Received: 21 April 2021 | Revised: 16 June 2022 | Accepted: 22 June 2022

DOI: 10.1002/tea.21808

JRST | WILEY

RESEARCH ARTICLE

# Enhancing science performance of middle-school students with and without developmental and behavioral-based disabilities using the Content Acquisition Podcast Professional Development approach

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**Funding information**
Institute of Education Sciences, Grant/Award Number: R324B130023

**Abstract**

Understanding science allows students with and without developmental and behavioral-based (DB) disabilities to better appreciate the world around them as well as prepare them for the growing science-related job market. However, students in the United States consistently underperform on science achievement tests compared to students from other nations. This underperformance could be attributed, in part to science having many specialized vocabulary terms that are not often taught explicitly, leaving students with incomplete or inaccurate understandings of word meanings. Improving science vocabulary instructional practices may support students with and without DB disabilities in enhancing their

science achievement. To address this need, researchers implemented multicomponent multimedia professional development (PD) to support middle-school science teachers in delivering high-quality vocabulary instruction in inclusive settings. In this paper, data collected from a study evaluating the efficacy of the PD were analyzed to determine the influence on student outcomes using ANOVA and multilevel modeling methodologies. Though initial results indicate a promising impact on teacher instructional practices, little is known whether teacher participation in the PD affected student science vocabulary and content knowledge growth. Using multilevel modeling, student science knowledge growth was evaluated following their teachers' exposure to the PD. The findings from this study indicate having indirect exposure to PD had a positive effect on science content knowledge for students with and without DB disabilities ($N = 980$). In addition, the authors found students with DB disabilities whose teachers had access to PD showed a larger gain in science knowledge than general education students whose teachers did not have access to the PD.

**KEYWORDS**

multimedia, professional development, science vocabulary, students with DB disabilities, vocabulary instruction

## 1 | INTRODUCTION

Scientific phenomena occur in everyday life. Understanding of contemporary issues, such as how to respond to a pandemic, risks of living near a gas pipeline, or dealing with the presence of lead in drinking water, is enhanced through scientific knowledge (Morgan et al., 2016). With additional knowledge, students and adults can develop or advocate for solutions to address issues of importance in their community as well as protect themselves and their families. However, many students enter adulthood lacking essential knowledge and skills in science (National Research Council, 2012). In fact, in the United States, students across grade levels continue to underperform in science achievement based on national assessment standards (National Assessment for Educational Progress [NAEP], 2018). This lack of proficiency is more pronounced for the broad group of students with disabilities, as 66% scored below basic compared to 28% of their general education peers on a science achievement assessment (NAEP, 2018). Students with developmental and behavioral-based disabilities (e.g., learning

disabilities, autism spectrum disorder, emotional behavioral disorders, attention deficit hyperactivity disorder, and intellectual disabilities) often face significant challenges in learning science content and performing well on measures such as the NAEP along with state and unit-level assessments.

A contributing factor to these results is documented by Kahn and Lewis (2014) who surveyed a national sample of K-12 science teachers and found that one-third reported not receiving training to teach students with disabilities. Of those who reported receiving training, many acquired it on the job, which suggests that the first opportunity for many science teachers to become informed in instructing students with disabilities is after they have already begun to teach. In addition, science teachers often feel that they do not have the time or resources to teach their students with disabilities adequately (Kahn & Lewis, 2014). As such, it is crucial that the professional development (PD) provided to science educators not only is relevant and addresses their needs but also provides resources and support.

In this article, we report results from a randomized control trial of a multicomponent, multimedia professional development process on the vocabulary instruction of middle-school science teachers in inclusive classrooms and the corresponding impact on their students with and without developmental and behavioral-based (DB) disabilities. Given the necessity of literacy skills within modern science standards, we highlight the need for middle-school science teachers to provide explicit and systematic vocabulary instruction to support the unique needs of many students with disabilities.

## 1.1 | The role of vocabulary within the science classroom and the need for explicitness

The National Research Council (NRC) emphasizes student engagement in inquiry-based investigations with rich opportunities to communicate and collaborate with their peers in order to learn science content (2012). For students to communicate ideas effectively in the classroom, participate in investigations, and be successful in fully understanding content, it is necessary to learn and understand underlying science terms and concepts (Parsons & Bryant, 2016). However, many terms used within the science classroom are not commonly used in students' everyday lives.

Being able to understand the meaning of a scientific term or phrase and apply it toward science content is an expectation within the Common Core Standards (Scruggs et al., 2013). For example, one of the English Language Arts standards for science and technical subjects state that students must be able to "determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context…" (Common Core State Standards, 2020). To meet this expectation, students must understand the meaning of terms such as "convection," "sublimation," or "phenotype" and apply it to the science lessons and investigations. Cervetti et al. (2012) suggested that multiple exposures to a concept or word could enhance the student's knowledge allowing them to better understand new, more complex information. Additionally, students who had literacy instruction embedded within science curriculum understood the big ideas better and could communicate these concepts using the new vocabulary terms in their writing (Cervetti et al., 2012). As such, to provide effective instruction, science teachers should utilize evidence-based science and literacy practices (Block, 2020; Wellington & Osborne, 2001).

### 1.1.1 | Limited quality and quantity of vocabulary instruction

Despite the importance of vocabulary instruction, many science teachers do not teach it explicitly (Kennedy et al., 2017). There are several reasons why. First, some educators are concerned that explicit science vocabulary instruction takes away time needed for teaching content and concepts (Guthrie & Klauda, 2012). Science teachers also expect students to learn the term meanings naturally through communicating and engaging in the activities and investigations provided during class time (Lee et al., 2019). In addition, science educators report feeling underprepared to provide effective vocabulary instruction (Johnson & Massey, 2012). However, students' science vocabulary knowledge growth is significantly associated with whether their teachers explicitly taught the term meanings (Carrier, 2013). As explored in the next section, students with DB disabilities face substantial struggles in science when new terms are not taught explicitly.

## 1.2 | Impact of developmental and behavioral-based disabilities on science vocabulary acquisition

The achievement discrepancy between students with and without DB disabilities could be attributed, in part, to the highly technical vocabulary used in the science classroom. Specifically, science includes a large number of specialized vocabulary words, some of which have alternative meanings in other contexts, such as revolution or solution (Mason & Hedin, 2011; Wellington & Osborne, 2001). For this population of students, the processing speed and accuracy required to acquire numerous pieces of complex information in rapid and often overlapping succession, while attempting to sort and store content within working and long-term memory is simply not realistic if specially designed scaffolds and instructional approaches are not in place (Swanson, 2015; Swanson et al., 2009).

Whereas general education students often develop and use memorization strategies to learn word meanings (Harmon et al., 2005; Songer & Linn, 1991), students with DB disabilities often lack effective strategies to learn vocabulary words (Harmon et al., 2005). As such, these students require vocabulary instruction that is both explicit and systematic to provide the firm foundation necessary to learn and then apply new vocabulary knowledge to scientific problems (Kaldenberg et al., 2015; Therrien et al., 2011). We detail specific evidence-based vocabulary practices for this population in the next section.

An understanding and appreciation of the learning needs of this population of students are needed considering the variability of the effectiveness between some prevailing teaching methods. An example is students with specific learning disabilities in the area of reading. These students often face breakdowns in how their working memory takes in auditory and visual information, activation of schemas in long-term memory, and forging new learning connections. In plain terms, if the teacher mentions the definition of a new term orally, and then quickly moves on to discuss its relationship to other terms and concepts, the student with a learning disability may be sitting confused trying to picture and integrate just the new definition with existing schemas in long-term memory while having given no active cognitive processing to the additional information provided by the teacher (Kennedy & Romig, 2021). As students get older and realize this cycle of frustration and academic failure, they can become deeply disengaged from learning with additional unwanted outcomes (Blondal & Adalbjarnardottir, 2012; Finn, 1989). Table 1

**TABLE 1** DB disability characteristics and associated impacts on vocabulary learning

| Disability | Characteristics impacting vocabulary learning |
|---|---|
| Specific learning disability (SLD)[a] | • Often lack strategies to learn complex vocabulary efficiently (e.g., memorization strategies like rehearsal)<br>• May have information-processing difficulties, which could make processing complex information such as technical terms and definitions difficult |
| Emotional or behavioral disorder (EBD)[b] | • Expressive and receptive language disorders are often co-occurring with emotional and behavioral disorder, making acquiring new language (e.g., complex terms and definitions) challenging<br>• May have a co-occurring learning disability, which brings many of the characteristics of specific learning disabilities mentioned above.<br>• Lack of emotional regulation can make persevering through difficult academic tasks (e.g., learning complex terms and definitions) difficult |
| Attention deficit hyperactivity disorder (ADHD)[c] | • May not pay attention to details, which could lead to difficulties in distinguishing between similar terms (e.g., revolution and rotation, meiosis and mitosis)<br>• May have difficulty organizing information leading to challenges with categorizing and classifying terms and definitions<br>• May have executive functioning limitations, which may make processing complex information challenging |
| Autism spectrum disorder (ASD)[d] | • Difficulty in social interaction which could inhibit language development due to lack of opportunity to develop word knowledge socially; however, language skills vary within ASD (i.e., strengths and weak areas differ)<br>• Could have difficulties with making inferences and comprehending texts, which may lead to challenges in understanding topics and term meanings |
| Intellectual disabilities (ID)[e,f] | • Difficulty with information processing as well as transferring and generalizing knowledge can make learning new topics and terms challenging<br>• Understanding abstract concepts can be difficult<br>• May struggle with critical thinking and reasoning skills |

Abbreviation: DB, developmental and behavioral-based.
[a]Johnson et al. (2010)
[b]Rock et al. (1997)
[c]Fuermaier et al. (2015)
[d]Lucas and Norbury (2014)
[e]Miller et al. (2013)
[f]Stavroussi et al. (2010)

presents a brief overview of students with DB disabilities and their unique challenges learning vocabulary in science.

Researchers have investigated ways to enhance the science vocabulary of students with DB disabilities. For example, Knight and colleagues (2012) investigated whether the incorporation of explicit instruction within science lessons would enhance the science vocabulary knowledge and comprehension of students with autism and intellectual disabilities. Specifically, they included strategies such as the model-lead-test approach, and providing

examples and nonexamples. They found that using explicit instruction strategies increased the number of correct responses related to the targeted terms as well as supported generalizing their knowledge about these terms in inquiry-based investigations. Cavanaugh and colleagues (1996) investigated the use of response cards to support the science vocabulary knowledge growth of students with learning disabilities, emotional behavioral disabilities, and intellectual disabilities. They compared the use of response cards to having the students learn the words passively. They found that when students were more actively involved in learning the science vocabulary, they performed higher on the science vocabulary tests than when they learned about terms passively.

### 1.2.1 | Evidence-based practices for vocabulary instruction of students with cognitive and psychological based disabilities

To achieve the level of knowledge needed for students to engage in scientific investigations, it is likely that students would need specially designed, evidence-based vocabulary instruction (Apanasionok et al., 2019); however, it is documented that evidence-based vocabulary instruction does not occur consistently in the science classrooms (e.g., Kennedy et al., 2017; Mason & Hedin, 2011).

Researchers have found that some of the most effective strategies to teach vocabulary to students with DB disabilities include: (a) student-friendly definitions; (b) multiple exposures to the word; (c) student discussions and engagement; and (d) interesting, diverse examples of term use (Beck & McKeown, 2007). Reviewing prior knowledge related to the vocabulary term and using images has also been found to improve vocabulary knowledge (Kuder, 2017).

One approach that combines these practices is Content Acquisition Podcasts (CAPs). CAPs consist of short multimedia presentations that are designed based on the Cognitive Theory of Multimedia Learning (CTML) and associated instructional design principles (Mayer, 2008, 2020). CAPs are not really podcasts but are instead flexible instructional materials teachers can employ to support a range of student needs.

### 1.2.2 | Cognitive theory of multimedia learning framework

The CTML (Mayer, 2020) was developed based on three assumptions. First, individuals learn new information through what they see and hear (i.e., dual processing principle; Paivio, 1986). Second, the amount of information we can keep visually and auditorily is limited (i.e., limited capacity assumption based on cognitive load theory; Baddeley, 1999; Chandler & Sweller, 1991). Third, learners organize and integrate relevant information with their prior knowledge (i.e., active processing assumption; Mayer, 2020; Wittrock, 1989). Designing instruction with these assumptions in mind is important for all students but especially for those with disabilities, as they often have difficulty with memorization and information-processing skills (Bryant et al., 2017). In accordance with the instructional design principles suggested by CTML, CAPs incorporate the strategic use of vivid images, minimal text, and evidence-based practices such as student-friendly definitions, examples and nonexamples, and explicit instruction (Kennedy et al., 2015) in order to reduce cognitive load. Additionally, CAPs include cues to signal essential content, focus on one word or

topic at a time, and provide opportunities for the learner to make connections between new information and their prior knowledge.

### 1.2.3 | More about CAPs

There are different types of CAPs based on the audience and purpose of the tool. Specifically, there are Content Acquisition Podcasts for Students (CAP-S), Content Acquisition Podcasts for Teachers (CAP-T), and Content Acquisition Podcasts for Teachers with Embedded Videos (CAP-TV). In Kennedy and colleagues' studies (2017, 2018), CAP-TVs were primarily used to provide instruction to in-service science teachers on use of targeted vocabulary practices. In addition to the standard format described above for CAPs, CAP-TV also provides the teachers with video models demonstrating how to implement the targeted practices with fidelity (Kennedy et al., 2018).

CAP-S are short, multimedia instructional vignettes that use images in time with audio to deliver instruction for one vocabulary term at a time. CAP-S can be viewed as many times as students need. A sample CAP-S can be seen at https://vimeo.com/644933204. Unrecorded CAP-S slides can also be used by teachers (see details below). Each CAP-S follows an instructional sequence of reviewing key background information, providing a student-friendly definition, and delivery of relevant examples and nonexamples. Vivid anchor images are used to help students develop a mental image of the term and connect it to the definition.

VanUitert et al. (2020) used CAP-S to teach science vocabulary terms to students with and without disabilities. They wanted to know whether having access to CAP-S to learn about word meanings made a significant difference in the science vocabulary achievement of participating students with learning disabilities. In addition, they investigated whether the number of views of CAP-S predicted the overall science vocabulary achievement of the students. VanUitert and colleagues found that when students with learning disabilities had access to the CAP-S, they outperformed on science vocabulary measures compared to their peers who learned about the words from their teachers' usual science vocabulary instructional methods. Additionally, among students who watched the CAP-S, increased viewership predicted improved science vocabulary performance.

### 1.2.4 | Need for more research on implementing evidence-based vocabulary practices with students with cognitive and psychological based disabilities

Despite knowledge about effective practices, few studies focus on developing secondary-school science teachers' skills in providing vocabulary instruction to students with disabilities. For example, Lauterbach et al. (2020) investigated whether using the Project MAP program to provide professional development to science teachers would enhance their knowledge and implementation of morphological awareness practices as well as increase their students' science vocabulary knowledge. Researchers found that participating teachers had significantly higher morphological awareness instruction and used more morphological vocabulary instruction strategies after receiving professional development (Lauterbach et al., 2020). Student vocabulary assessment data showed increased science vocabulary knowledge between pre- and post-tests. Studies conducted on the use of the Content

Acquisition Podcast Professional Development (CAP-PD) process are noted below as they related directly to the present study.

## 1.3 | Content Acquisition Podcast Professional Development process

To assist science teachers in providing evidence-based vocabulary instruction during lessons, Kennedy et al. (2017) developed the CAP-PD process. The CAP-PD was developed to help support inclusive science teachers' knowledge of and readiness to implement the aforementioned evidence-based vocabulary practices. CAP-PD consists of three components: (a) asynchronous multimedia instruction that builds teacher content and procedural knowledge of target skills through multimedia modeling presentations for teachers (see https://vimeo.com/448122821 for a sample); (b) CAP-S that teachers can use during instruction, which include evidence-based practices that teachers were exposed to within modeling videos (see www.vocabsupport.com for samples); and (c) individualized feedback provided through email based on live classroom observations using the Classroom Teaching (CT) Scan, a descriptive observation tool used to capture teachers' use of instructional practices (Kennedy et al., 2017). We detail the CT Scan and its functionality along with notes on the subsequent coaching in the methods section.

### 1.3.1 | Empirical evidence for CAP-PD

To test the effectiveness of CAP-PD, Kennedy et al. (2017) used a multiple-baseline across participants single-case experimental design over a 6-week period to determine whether CAP-PD increased teachers' use of evidence-based vocabulary practices and whether teachers believed the CAP-PD process had social validity. Three seventh-grade science teachers participated in this study. Researchers completed a total of 85 observations using the CT Scan, allowing them to record the amount of time teachers spent teaching vocabulary words using the strategies taught in the CAP-TVs and emphasized in CAP-S slides. Additionally, researchers recorded the number of practices used with fidelity. The authors found that, following the CAP-PD intervention, participating teachers allocated more instructional time towards teaching vocabulary word meanings and used more of the vocabulary instruction practices taught (Kennedy et al., 2017).

In a subsequent study, the authors provided the CAP-PD intervention to 28 middle-school teachers who worked in inclusive classrooms in rural school districts (Kennedy et al., 2018). Using a randomized control trial design, participating teachers either received the total CAP-PD process (experimental group) or had access to only the CAP-S without being able to access the CAP-TV or receive feedback (comparison group). Researchers found that while both groups increased the amount of time they spent on science vocabulary instruction, the CAP-PD group spent a significantly longer amount of time explicitly teaching the term meanings compared to the CAP-S only teachers.

Although the focus of the study was to develop teachers' abilities to provide evidence-based vocabulary instruction to middle-school students, Kennedy et al. (2018) gathered data about the students' science and related vocabulary knowledge. They found that students with DB disabilities whose teachers had access to CAP-PD significantly outperformed their peers whose teachers only had access to the CAP-S on the vocabulary assessments. Specifically, they found this intervention had a medium effect on student outcomes on the science content measure

($d = 0.54$) and a small to medium effect size on the three vocabulary assessments ($d = 0.33$, 0.73, and 0.70, respectively).

These observed positive effects of the CAP-PD on student achievement stem from teachers' implementation of aforementioned evidence-based practices for students with DB disabilities. More time spent on terms by teachers leads to additional opportunities for students to move the new information from working to long-term memory. In addition, the CAP-PD process stresses use of images, student-friendly language, relevant examples, and ongoing opportunities for students to respond to prompts and receive feedback. As noted, the combinations of these effective practices delivered routinely by a teacher who recognizes the importance of vocabulary is essential.

### 1.4 | Study purpose

The purpose of the present study is to explore the relationship between students' science achievement and their indirect exposure to CAP-PD, their average science vocabulary performance, and their DB disability status, by analyzing data from a randomized control trial study. The term indirect exposure refers to the fact that students do not participate in the CAP-PD, their teachers do. Specifically, using proximal curriculum-based measures (CBM) and the more distal *Misconceptions-Oriented Standards-based Assessment Resources for Teachers* (MOSART; Kim et al., 2015) for pre- and post- assessment data, we explore the following questions:

1. To what extent does teacher participation in the CAP-PD make a difference in the post-MOSART scores of their students with and without DB disabilities?
2. To what extent is student DB disability status associated with science achievement, as measured by student post-MOSART scores holding English proficiency, teacher CAP-PD participation, and pre-MOSART scores constant?
3. To what extent is the interaction between DB disability status and teacher participation in the CAP-PD associated with student post-MOSART scores holding English proficiency and pre-MOSART scores constant?
4. To what extent are student average curriculum-based measures (CBM) scores associated with science achievement as assessed by post-MOSART assessment scores holding DB disability status, pre-MOSART assessment scores, teacher access to CAP-PD, and English proficiency constant?

## 2 | METHODS

We conducted a randomized-control trial study testing the effect of providing CAP-PD to science teachers in inclusive classrooms on their students' vocabulary and science content knowledge. In the published data from Kennedy et al.' (2018) study, the treatment group had access to the CAP-PD whereas the control group had access to unrecorded CAPs for students. In contrast, the unpublished data originate from a second randomized-control investigation where the teachers in the control group used their usual vocabulary teaching practices compared to the teachers who participated in the CAP-PD (treatment group).

**TABLE 2** Descriptive statistics of representation of student disability categories

| Disability category | *N* | Percentage (%) |
|---|---|---|
| No diagnosed disability | 863 | 88 |
| Specific learning disability | 55 | 5.6 |
| Emotional disturbance | 16 | 1.6 |
| Autism spectrum disorder | 11 | 1.1 |
| Attention deficit hyperactivity disorder | 25 | 2.5 |
| Intellectual disability | 10 | 1.0 |

## 2.1 | Sample

Participants included 980 sixth-grade students drawn from 13 inclusive science classrooms spread across four rural school districts in the United States. Demographic information originated from teacher records. Specifically, teachers assigned anonymous codes for their students that included student demographic information. Researchers had access only to the anonymous codes whereas the teachers maintained the master list, which connected the student to the code. After receiving university and district consent, families were informed of the study and were given the option to opt their child out of the data collection activities. Of these students, 51.3% were male and 48.7% were female; 73.4% of the students were White, 6.3% were Latinx, 16.2% were Black, 2.6% were Asian, and 1.53% identified as being of two or more races. Approximately 67% of students were eligible for free/reduced lunch. Of the participants, 12% were identified as having a DB disability, broken down by disability type in Table 2. Although it is possible for some of the students to have had more than one DB disability, students in this study were classified by the primary DB disability identified in the Individualized Education Plan. Among students with a DB disability, 45% had a teacher who participated in CAP-PD ($N = 52$) and 55% had a teacher who did not participate in CAP-PD ($N = 64$). Approximately 47% of students without a DB disability had a teacher who participated in the CAP-PD ($N = 405$) and about 53% of students without a DB disability had a teacher who did not participate in the CAP-PD ($N = 459$). More information about the student demographics by teacher is available in Table 3.

The participating students came from six middle schools representing four school districts in rural areas of the Mid-Atlantic region. The schools had an average of 564.7 students. All of the 13 participating teachers were White, with the majority (69.2%) identifying as women. Educationally, the highest degree earned by 53.8% of the sixth-grade teachers was a Master's degree, and, on average, the participants had taught for 13.3 years.

## 2.2 | Measures

### 2.2.1 | Misconceptions-Oriented Standards-based Assessment Resources for Teachers (MOSART)

Researchers used the MOSART as the distal measure of student science performance. MOSART is a 72-item multiple-choice measure that consists of four subscales: astronomy, earth science,

**TABLE 3** Student demographic information by teacher

| Teacher | # class | CAP-PD? | Total N | Student race N | | | | | Student gender N | | Student disability N | | Disability type N | | | | | Multilingual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | B | W | L | A | T | Female | Male | Yes | No | LD | EBD | ADHD | ASD | ID | |
| A | 5 | N | 119 | 22 | 83 | 8 | 3 | 3 | 53 | 66 | 10 | 109 | 3 | 3 | 2 | 1 | 1 | 0 |
| B | 5 | N | 105 | 15 | 76 | 9 | 2 | 3 | 47 | 58 | 8 | 97 | 3 | 0 | 5 | 0 | 0 | 1 |
| C | 4 | Y | 80 | 15 | 56 | 7 | 1 | 1 | 42 | 38 | 13 | 67 | 6 | 0 | 3 | 2 | 2 | 4 |
| D | 3 | N | 53 | 10 | 40 | 2 | 1 | 0 | 31 | 22 | 10 | 43 | 3 | 2 | 3 | 1 | 1 | 0 |
| E | 3 | Y | 62 | 7 | 45 | 6 | 2 | 2 | 35 | 27 | 9 | 53 | 5 | 2 | 0 | 1 | 0 | 8 |
| F | 5 | N | 91 | 11 | 76 | 1 | 2 | 1 | 44 | 47 | 14 | 77 | 4 | 2 | 3 | 2 | 3 | 0 |
| G | 4 | Y | 63 | 5 | 45 | 9 | 3 | 1 | 31 | 32 | 7 | 56 | 6 | 0 | 1 | 0 | 0 | 7 |
| H | 4 | Y | 70 | 12 | 52 | 3 | 1 | 2 | 26 | 44 | 9 | 61 | 7 | 1 | 1 | 0 | 0 | 0 |
| I | 4 | Y | 93 | 19 | 66 | 5 | 3 | 0 | 43 | 50 | 7 | 86 | 3 | 0 | 3 | 0 | 1 | 1 |
| J | 4 | N | 92 | 12 | 73 | 3 | 2 | 2 | 46 | 46 | 11 | 81 | 6 | 1 | 3 | 0 | 1 | 2 |
| K | 1 | N | 20 | 5 | 15 | 0 | 0 | 0 | 10 | 10 | 4 | 16 | 2 | 1 | 1 | 0 | 0 | 0 |
| L | 5 | Y | 89 | 14 | 66 | 6 | 3 | 0 | 47 | 42 | 8 | 81 | 4 | 2 | 0 | 1 | 1 | 0 |
| M | 2 | N | 43 | 12 | 30 | 3 | 2 | 0 | 22 | 21 | 7 | 36 | 3 | 2 | 0 | 2 | 0 | 4 |

Abbreviations: A, Asian; ADHD, attention deficit hyperactivity disorder; ASD, autism spectrum disorder; B, Black; CAP-PD, Content Acquisition Podcast Professional Development; EBD, emotional behavioral disability; ID, intellectual disability; L, Latinx; LD, learning disability; T, two or more races; W, white.

life science, and physical science (Kim et al., 2015). It can be used to assess student and/or teacher science knowledge. The reported internal reliability of the MOSART measure has an alpha coefficient ranging from 0.7 to 0.9 (Wendt & Rockinson-Szapkiw, 2014). For the purposes of this study, the subtest covering physical science was utilized for a total of 15 possible points given the focus of the sixth-grade course on physical science. The student's posttest scores on the MOSART serve as the dependent variable, whereas the pretest scores serve as one of the covariate variables. The reliability alpha for the students who took the physical science subtest in this study was 0.82 for the posttest. The MOSART subtest was given as a pretest at the beginning the school year and then again at mid-year following the teacher's final observation. Some content on the MOSART physical science subtest was not taught by study teachers due to timing of the study in addition to content included within state standards.

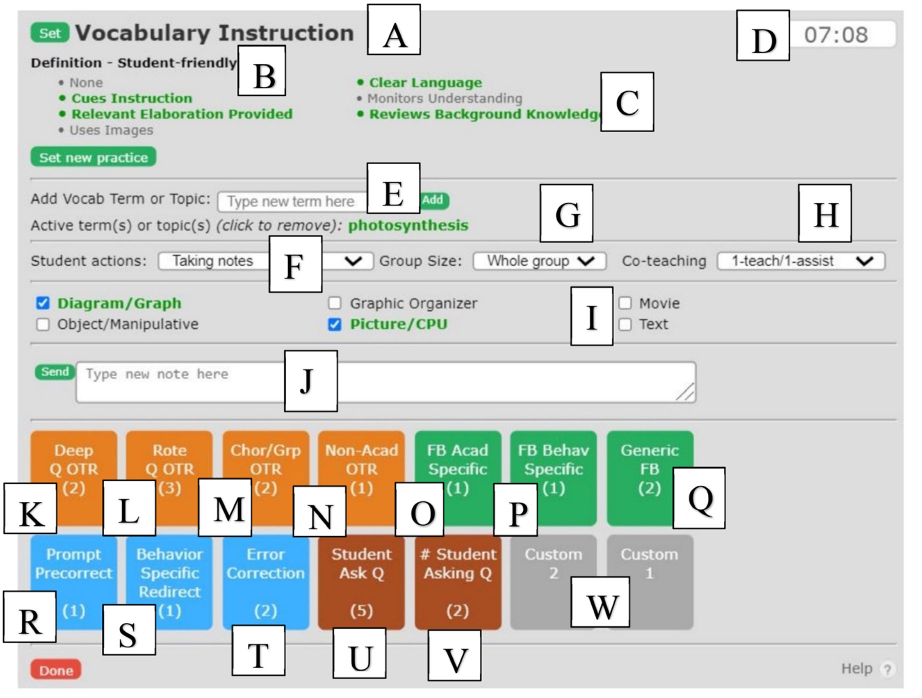
### 2.2.2 | Curriculum-based measures

Students completed three proximal multiple-choice vocabulary curriculum-based measures (CBMs) in order to monitor progress throughout the course of the study. CBMs are used to provide a reliable and valid assessment of student progress on achieving a skill (Conoyer et al., 2020; Espin et al., 2013). In this study, the CBMs were 20 multiple-choice items where the term was the stem (e.g., Atoms are…) and then five answer choices were provided (i.e., the answer, three distractors, and I do not know). The terms were randomly drawn from the full curriculum for each probe using procedures outlined by Espin and colleagues. The mean of the three probes was used as an independent variable to determine whether a student's average performance on these vocabulary-based measures was associated with their MOSART posttest outcomes. The reliability alpha was consistent across the three CBMs: 0.85, 0.83, and 0.87. CBMs were administered once per month following the teachers' fourth through sixth observations by researchers.

## 2.3 | Design

We employed a randomized controlled trial in which 13 sixth-grade science teachers were randomly assigned to two groups: six teachers were placed in the CAP-PD intervention group, and seven teachers served as the comparison group, using their typical vocabulary instruction methods. Regardless of the assigned condition, each participating teacher was observed six times with their instructional moves recorded using the CT scan. The purpose of the first three observations was to create a baseline of teacher vocabulary instruction, whereas the latter three were to determine the duration of vocabulary instruction and the frequency of evidence-based vocabulary practices used post-intervention.

Baseline observations occurred during the first 3 weeks of the school year. To reduce bias, researchers were blinded to which teachers were in the CAP-PD and control conditions. In the control condition, teachers used their usual practices. Researchers wrote coaching emails following baseline observation number three for all teachers (see details below). The emails were sent to an independent third party who maintained the list of teacher assignments and either forwarded or withheld the emails. Teachers in the CAP-PD condition received access to a library of CAP-S slides and the CAP-TV library with instructions on how to use each. Teachers were instructed to watch each CAP-TV at least once, and then were referred to watch the videos




A. Broad category being used by teacher

B. Specific practice being implemented

C. Implementation markers for practice (green observed, black not observed)

D. Time of observation (running clock)

E. Window to record content being taught

F. Document what students are supposed to be doing

G. Which teacher and group size

H. Co-teaching model being used

I. Visual aids being used (check = active)

J. Window to take qualitative notes

K. Count of deep, probing OTRs

L. Count of rote OTRs

M. Count of choral/group OTRs

N Count of non-academic OTRs

O. Count of academic-specific Praise

P. Count of behavior-specific Praise

Q. Count of generic Praise

R. Count of prompts or precorrections academic

S. Count of behavior specific redirect

T. Count of error correction

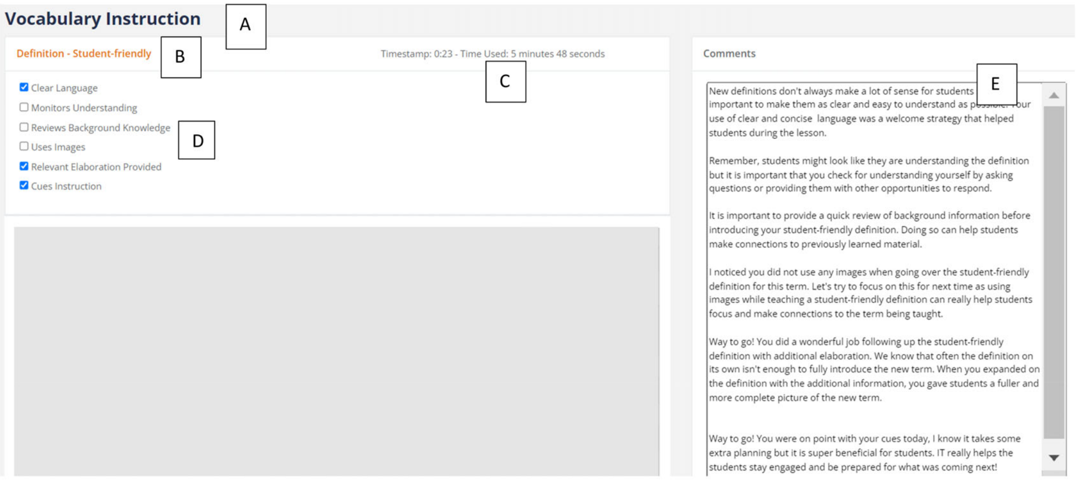
U. Count of questions asked by students

V. Count of number of students asking questions

W. Custom buttons

**FIGURE 1** Classroom teaching scan Interface

additional times within coaching reports (see below). Some of the evidence-based vocabulary practices teachers received instruction on included providing student-friendly definitions, examples and nonexamples, word parts, and demonstrations. Teachers in the control condition received nothing from researchers other than communications to schedule observations and assessments. Following baseline, the teachers in the treatment group received the CAP-PD. The researchers scheduled to observe each teacher from both groups once per month across the fall semester. Observers asked teachers to teach at least some vocabulary on days they agreed to be observed, and the researchers stayed for the entire lesson (typically




A. Category being taught

B. Teacher practice that was implemented

C. Duration practice was used

D. Implementation markers observed and not observed

E. Automatically generated feedback statements based on whether implementation marker was observed or not

**FIGURE 2** Sample feedback form

50 minutes). The CT Scan observation tool was used to document what practices were used and for how much time.

The CT Scan is a low-inference observation tool that allows an observer to record what practices the teacher used in real time. It is available free within the COACHED web app (www.coached.education.virginia.edu) and a labeled screen shot is contained in Figure 1. The CT Scan allows the observer to document the broad category of practice (e.g., vocabulary, classroom management, science inquiry), the specific practice (e.g., student-friendly definition, example), and implementation markers of quality associated with each practice (e.g., uses cues, clear language, reviews background knowledge, uses images, elaborates on definition, confirms understanding). The observer and teacher use the time feature of the CT Scan to record how much time was spent using certain practices. For instance, some of the evidence-based vocabulary practices tracked in this study included providing student-friendly definitions, examples and nonexamples, opportunities to discuss the term meaning, and highlighting parts of the words. Observers can also record the specific term or topic being taught, what students were supposed to be doing (e.g., taking notes, answering questions), the group size (e.g., whole, small, individual), any visual aids being used (e.g., pictures, graphic organizers, object), and take qualitative notes. Finally, they can record each question the teacher asked, feedback statements, and other countable data. All data recorded in the CT Scan align with the time they occur and overlay to give an unbiased and comprehensive look at the lesson without needing to assign a quality score. The quantitative data gathered "speak for themselves" and can be used to generate coaching and feedback reports.

The coaching emails were written using data from the CT Scan following each observation. Figure 2 has a labeled screen shot of the feedback form. The feedback notes were tied to the specific implementation markers either observed or not for each practice. For example, if the teacher used clear language when delivering a student-friendly definition, the observer might write "using clear language is critical for students with DB disabilities because you don't want to use other words they may not know. Clear language gives them the best chance for learning success. You did an awesome job today being super clear with your language—keep it up!" If the teacher did not use images, the observer might write "I didn't see you using images to support your students' learning when doing vocabulary today. This is really important because many students do not have mental images already in place to visualize new terms or concepts, and providing them with one can really make a difference. If you use the CAP-S slides we provided, you will find a trove of images. You can also see a teacher modeling use of vocabulary with images at the 7:30 mark of the CAP-TV for this practice. I'd love to see you using images during my next visit." This process would repeat for each practice the teacher used during the lesson. The feedback would also note total numbers of opportunities students had to respond, feedback statements, and a range of other data. For a more detailed explanation of the feedback process, please see Kunemund et al. (2021, 2022).

## 2.4 | Data analysis

Analysis of variance (ANOVA) was conducted to assess whether significant differences were present between students with and without DB disabilities in classes where teachers participated in the CAP-PD and those who did not on their MOSART post-assessment scores. First, a two-way factorial ANOVA was conducted, which included DB disability status and access to a teacher who participated in the CAP-PD serving as independent variables. The homogeneity of variance was analyzed, and the effect size was determined using the Cohen's d statistic. Since, DB disability status and teacher CAP-PD participation consisted of two groups each, in order to analyze differences between groups, a new variable was created, which coded the participants into one of four groups (i.e., students without DB disabilities whose teacher participated in CAP-PD, students with DB disabilities whose teacher participated in CAP-PD, students without DB disabilities whose teacher did not participate in CAP-PD, and students with DB disabilities whose teacher did not participate in CAP-PD). A one-way ANOVA was conducted with this variable to also be able to investigate differences between groups on the MOSART posttest scores using post hoc testing.

It was decided to use ANOVAs instead of multilevel modeling for the first question in order to provide a simpler initial analysis of differences between the groups focused upon in this study. In addition, student participants were recoded so that each group are given their own unique code based on their DB disability status and teacher CAP-PD participation. This allowed for conducting a one-way ANOVA post hoc test to analyze differences between groups.

As with most school-based research, students were nested within teachers' classrooms, which were nested within schools. There are three levels of nesting in this study: (a) students (Level 1), (b) class (Level 2), and (c) teacher (Level 3). The students form the foundation of this model as the Level 1 variable. The students belong to specific classes (Level 2), and a teacher (Level 3) provides instruction to a set of classes. In total, at Level 2 there were 48 classes, and at Level 3 there were 13 participating sixth-grade teachers. The participating teachers taught multiple classes each. Random assignment to create a treatment group, while underpowered,

occurred at Level 3. All of the classes taught by a particular teacher received the same type of instruction, and likewise all of the students within those classes received the same instruction. At Level 1, multiple covariates (DB disability status, English proficiency, MOSART pretest scores, and average CBM scores) were included. These variables were centered as the students (and their related characteristics) should be tied to their specific classes (Level 2). At Level 2, the classrooms were centered around the teacher means (Level 3). This prevented confounding these levels of the model and allows for only within variance to remain. At Level 3 the treatment variable (group) was included. Student DB disability status and group membership were dummy coded. The variables of English proficiency, MOSART pretest scores, and, for one of the questions, average CBM scores were included in order to control for the influence these factors may contribute to the association between the MOSART posttest scores and the students' DB disability status and whether their teacher participated in the CAP-PD. Without controlling for the influence of these variables, they may skew the degree of significance of the associations. For instance, it can be challenging for students learning English who are still developing their knowledge of academic and science-specific vocabulary in English to learn science without support (Garcia, 2005; Terrazas-Arellanes et al., 2018). As such, the multilingual variable was included to mitigate the potential influence it may have on the association between DB disability status and MOSART posttest scores.

Within the dataset, 42 student scores were missing from the posttest, 61 student scores were missing from the pretest, one measurement was missing for whether a student was a multilingual learner, and 117 student scores were missing from the average CBM score. An imputation of the data was run using Blimp, a statistical program used to address missing data. All other analyses were conducted using the statistical package STATA-IC 17.

A three-level random intercept model was used in this study and is as follows:

Level 1 (Student):

$$\text{MOSART posttest} = \beta_0 + \beta_1(\text{DB disability status}) + \beta_2(\text{MOSART pretest}) + \beta_3(\text{gender}) + \beta_4(\text{race}) + \beta_5(\text{CBM average}) + \text{error}$$

Level 2 (Classroom):

$$\beta_0 = b_{00k} + r_{0jk}\left[r_{0jk} \sim N\left(0, \sigma^2{}_{r0}\right)\right]$$

Level 3 (Teacher):

$$b_{00k} = \gamma_{000} + \gamma_{001}(\text{CAP access}) + u_{0k}\left[v_{0k} \sim N\left(0, \sigma^2{}_{v0}\right)\right]$$

The intraclass correlation coefficient (ICC) measures the proportion of variance between clusters as well as the correlation between two units within a cluster. For this study, the ICCs were hand-calculated using the following formulas:

$$\mathrm{ICC}_{\text{Students with Same Teacher}}: \text{Level 3 variance}/\text{total variance}$$

$$\mathrm{ICC}_{\text{Students in the Same Class with the Same Teacher:}}\ (\text{Level 2 variance} + \text{Level 3 variance})/\text{total variance}$$

## 2.5 | Treatment fidelity

The researchers monitored the teachers' implementation of taught practices in order to make sure a minimum level of performance was met. Teacher moves during the observed science lessons were recorded using the CT Scan. Prior to intervention, middle-school science teachers who received the CAP-PD intervention taught vocabulary-term meanings slightly longer ($M = 134.14$ s; SD $= 173.56$) than their colleagues who would not ($M = 107.73$; $SD = 155.11$); however, this difference was not statistically significant ($F(1{,}64) = 0.424$, $p = 0.517$).

Due to the violation of the homogeneity of variance ($F(1{,}111) = 22.192$, $p < 0.001$), a Welch ANOVA was used to analyze differences between the teachers who participated in the CAP-PD and those who did not. On average, teachers in the CAP-PD group spent 124% more time using evidence-based vocabulary practices compared to their colleagues that did not receive the CAP-PD ($M = 381.99$; $SD = 359.20$ and $M = 170.79$; $SD = 27.71$, respectively). This difference in time using the vocabulary practices was statistically significant ($F(1{,}110.693) = 19.20$, $p < 0.001$). On average, participants in the CAP-PD group used approximately three vocabulary strategies before receiving the professional development (range: 0–6 practices). After receiving the CAP-PD, the average number of used practices increased to about 13 (range: 8 to 18 practices). Teachers in the comparison group increased the average number of practices used from approximately four (range: 0–7 practices) in the first three observations to five for the last three observations (range: 1–7 practices). The most common practices used by the teachers included student-friendly definitions (22.15% of practices used), application of the terms (17.45%), and examples (16.11%). Two observers attended 20% of the observations for interscorer reliability purposes. An agreement of 100% on study variables of interest was achieved.

# 3 | RESULTS

To determine whether it was appropriate to group the scores of student participants with DB disabilities (i.e., learning disabilities, autism spectrum disorder, intellectual disabilities, attention deficit hyperactivity disorder, and emotional behavioral disabilities), analysis of variance was conducted to determine whether differences in performance were present between students from different DB disability categories. Students with these disabilities did not perform significantly different from each other during pretest ($F(4{,}105) = 0.42$, $p = 0.797$) and posttest ($F(4,\ 107) = 0.58$, $p = 0.675$), suggesting it is appropriate to analyze performance together.

We conducted ANOVAs to determine whether there were differences between students with and without DB disabilities at pretest on the MOSART physical science assessment. Students whose teachers had access to the CAP-PD had a mean score of 4.45 ($SD = 1.67$) compared to their peers whose teachers did not have access to the CAP-PD ($M = 4.79$,

*SD* = 2.00), a statistically significant difference ($F(1,917) = 7.78$, $p = 0.006$). This suggests that at the beginning of this study, students whose teachers would not have access to the CAP-PD were outperforming their peers in classrooms where teachers would have access to CAP-PD. Furthermore, both groups' MOSART scores were low (4.45 and 4.79 out of 15 possible points).

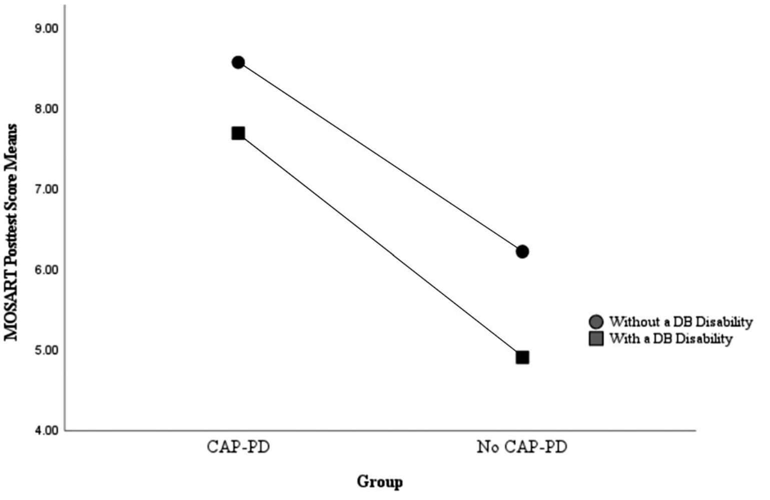



**FIGURE 3** Average MOSART posttest scores based on DB disability status and teacher CAP-PD participation

**TABLE 4** Descriptive analysis

| | SWOD whose teachers had access to CAP-PD | SWD whose teachers had access to CAP-PD | SWOD whose teachers did not access CAP-PD | SWD whose teachers did not access CAP-PD |
|---|---|---|---|---|
| | M (SD) | M (SD) | M (SD) | M (SD) |
| MOSART pretest | 4.49 (1.69) | 4.14 (1.50) | 4.87 (2.02) | 4.27 (1.75) |
| MOSART posttest | 8.55 (2.71) | 7.67 (2.31) | 6.20 (2.57) | 4.89 (2.00) |
| CBM 1 | 8.16 (2.23) | 7.04 (2.54) | 6.13 (2.17) | 4.68 (2.01) |
| CBM 2 | 10.56 (2.84) | 10.26 (2.54) | 7.38 (2.81) | 6.05 (2.50) |
| CBM 3 | 14.18 (2.57) | 13.04 (2.12) | 10.32 (3.50) | 8.15 (2.68) |
| CBM Average | 11.03 (2.10) | 10.06 (2.06) | 7.97 (2.01) | 6.29 (1.82) |
| EL | 0.03 (0.18) | 0.13 (0.34) | 0.01 (0.10) | 0.03 (0.18) |

Abbreviations: CAP-PD, Content Acquisition Podcast Professional Development; CBM, curriculum-based measures; EL, English learner which refers to multilingual students; MOSART, Misconceptions-Oriented Standards-Based Assessment Resources for Teachers; SWD, students with cognitive and psychological-based disabilities; SWOD, students without cognitive and psychological-based disabilities.

## 3.1 | Question 1 results

The first question asked in this study was: To what extent does having a teacher participate in the CAP-PD make a difference in the post-MOSART scores of students with and without DB disabilities?

To determine whether there were significant differences in MOSART pretest scores based on DB disability status, we ran an additional ANOVA. A significant difference in MOSART pretest mean scores was yielded between students without DB disabilities whose teachers had CAP-PD access ($M = 4.49$, $SD = 1.69$) and whose teachers who would not ($M = 4.87$, $SD = 2.02$; $F(1{,}807) = 7.97$, $p = 0.005$); however, the difference of 0.38 points is not educationally meaningful. For students with DB disabilities, there was not a statistically significant difference between those whose teacher would have access to the CAP-PD ($M = 4.14$, $SD = 1.50$) and those whose teachers would not ($M = 4.27$, $SD = 1.75$) in MOSART preset scores ($F(1{,}108) = 0.16$, $p = 0.687$). For a visual of mean differences between DB disability-status subgroups, see Figure 3. See Table 4 for descriptive analysis for the different participant groups.

Two-way factorial ANOVA analyses were conducted to determine whether students with and without DB disabilities performed better on the MOSART posttest when their teacher participated in CAP-PD compared to their peers whose teacher did not participate in CAP-PD. Specifically, analyses of the between-subject effects for DB disability status, teacher participation in CAP-PD, and their interaction effects were conducted. In addition, a Levene's Test was conducted to analyze the level of homogeneity of variance. Homogeneity of variance was violated, $F(3, 934) = 3.376$, $p = 0.018$, in part due to the varying sizes of the four groups (ranging from $N = 52$ to $N = 459$), since there are fewer students with DB disabilities represented in the school system than not. As such, the $F$-test was not a reliable measure for a factorial ANOVA. The results for the two-way ANOVA can be seen in Table 5 and comparisons between the groups can be seen in Table 6. Since multiple comparisons were made simultaneously in the factorial ANOVA, a Bonferroni correction was used to reduce the chance of a Type 1 error. Results from the factorial ANOVA indicate that teacher participation in CAP-PD had a large effect on their students' MOSART posttest scores ($d = 0.911$) whereas student DB disability status had a small effect ($d = 0.390$) on their MOSART posttest performance. The interaction between student DB disability status and teacher participation in CAP-PD had a negligible effect on student MOSART posttest performance ($d = 0.091$).

To better answer Question 1, the participants were split into one of four groups based on their DB disability status and their teacher's participation in CAP-PD. A one-way ANOVA was conducted to further analyze group means and conduct post hoc testing to determine whether significant differences existed between groups. Due to the continued violation of variance ($F(3{,}934) = 3.465$, $p = 0.016$), a Welch ANOVA was used, since it is not sensitive to heterogeneity of variance. A significant difference in performance was present between the four groups (Welch $F(3, 152.441) = 80.339$, $p < 0.001$). The effect size of the difference in student performance on the MOSART posttest between groups whose teachers participated in CAP-PD and those who did not was large ($d = 0.929$).

To closer evaluate differences between groups, a Games-Howell post hoc test was conducted. The Games-Howell post hoc test is used when homogeneity of variance cannot be assumed, since it is not sensitive to differences in variance. Students without DB disabilities whose teacher participated in CAP-PD ($M = 8.55$, $SD = 2.71$) did significantly better than students with DB disabilities whose teacher participated in CAP-PD ($M = 7.60$, $SD = 2.29$, $p = 0.04$), students without DB disabilities whose teacher did not participate in CAP-PD ($M = 6.20$, $SD = 2.57$, $p < 0.001$), and students with DB disabilities whose teacher did not participate in CAP-PD ($M = 4.89$,

**TABLE 5** ANOVA comparisons of posttest scores based on DB disability status and teacher CAP-PD access

| **Two-way ANOVA** | | | | |
|---|---|---|---|---|
| **Group** | **M Square** | ***df*** | ***F*** | ***d*** |
| DB disability status | 117.90 | 1, 938 | 17.64 *** | 0.390 |
| Teacher CAP-PD participation | 644.57 | 1, 938 | 96.42 *** | 0.911 |
| DB disability status × CAP-PD | 4.55 | 1 | 0.68 | 0.091 |

| **One-way ANOVA** | | | | |
|---|---|---|---|---|
| **Group** | **M (SD)** | ***df*** | ***F*** | ***d*** |
| SWOD whose teachers had access to CAP-PD | 8.55 (2.71) | 3, 152.44 | 80.34*** | 1.38 |
| SWD whose teachers had access to CAP-PD | 7.60 (2.29) | | | |
| SWOD whose teachers did not have access to CAP-PD | 6.20 (2.57) | | | |
| SWD whose teachers did not have access to CAP-PD | 4.89 (2.00) | | | |

| **Games-Howell post hoc test** | | | | |
|---|---|---|---|---|
| **Group** | **Group 2** | **M Difference** | **SE** | **95% CI** |
| SWOD whose teachers had access to CAP-PD | SWD-CAP-PD | 0.955* | 0.351 | 0.03 to 1.88 |
| | SWOD-NCAP-PD | 2.357*** | 0.184 | 1.88 to 2.83 |
| | SWD-NCAP-PD | 3.669*** | 0.290 | 2.91 to 4.43 |
| SWD whose teachers had access to CAP-PD | SWOD-CAP-PD | −0.955*** | 0.351 | −1.88 to −0.03 |
| | SWOD-NCAP-PD | 1.402*** | 0.346 | 0.49 to 2.31 |
| | SWD-NCAP-PD | 2.715*** | 0.412 | 1.64 to 3.79 |
| SWOD who teachers did not have access to CAP-PD | SWOD-CAP-PD | −2.357*** | 0.184 | −2.83 to −1.88 |
| | SWD-CAP-PD | −1.402*** | 0.346 | −2.31 to −0.49 |
| | SWD-NCAP-PD | 1.313*** | 0.284 | 0.57–2.06 |
| SWD whose teachers did not have access to CAP-PD | SWOD-CAP-PD | −3.669*** | 0.290 | −4.43 to −2.91 |
| | SWD-CAP-PD | −2.715*** | 0.412 | −3.79 to −1.64 |
| | SWOD-CAP-PD | −1.313*** | 0.284 | −2.06 to −0.57 |

*Note*: The *F* is the Welch *F* for the one-way ANOVA.

Abbreviations: CAP-PD, Content Acquisition Podcasts Professional Development; CI, confidence interval; NCAP-PD, No Content Acquisition Podcasts Professional Development; SE, standard error; SWD, students with developmental and behavioral-based disabilities; SWOD, students without developmental and behavioral-based disabilities.

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

**TABLE 6** Two-way ANOVA pairwise comparisons between groups

| Group 1 | Group 2 | Mean difference | SE | 95% CI Lower bound | 95% CI Upper bound |
|---|---|---|---|---|---|
| SWOD in CAP-PD group | SWOD in no CAP-PD group | 2.350*** | 0.180 | 1.997 | 2.704 |
| SWOD in no CAP-PD group | SWOD in CAP-PD group | −2.350*** | 0.180 | −2.704 | −1.997 |
| SWD in CAP-PD group | SWD in no CAP-PD group | 2.781*** | 0.491 | 1.819 | 3.744 |
| SWD in no CAP-PD group | SWD in CAP-PD group | −2.781*** | 0.491 | −3.744 | −1.819 |
| SWOD in CAP-PD group | SWD in CAP-PD group | 0.882* | 0.385 | 0.126 | 1.637 |
| SWD in CAP-PD group | SWOD in CAP-PD group | −0.882* | 0.385 | −1.637 | −0.126 |
| SWOD in no CAP-PD group | SWD in no CAP-PD group | 1.313*** | 0.354 | 0.619 | 2.007 |
| SWD in no CAP-PD group | SWOD in no CAP-PD group | −1.313*** | 0.354 | −2.007 | −0.619 |

Abbreviations: CAP-PD, Content Acquisition Podcasts Professional Development; CI, confidence interval; SE, standard error; SWD, students with DB disabilities; SWOD, students without DB disabilities.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

SD = 2.00, $p < 0.001$). Similarly, students with DB disabilities whose teacher participated in CAP-PD did significantly better on the MOSART posttest compared to students with and without DB disabilities whose teacher did not participate in CAP-PD ($p < 0.001$ for both groups). Students without DB disabilities whose teacher did not participate in CAP-PD did significantly better on the MOSART posttest compared to students with DB disabilities whose teacher did not participate in CAP-PD ($p < 0.001$). See Table 5 for more information.

## 3.2 | Question 2 results

The second question was: To what extent is student DB disability status associated with science achievement, as measured by student post-test scores holding race, gender, and pre-test scores constant? The intercept (6.04) is the grand mean of the MOSART posttest across the entire sample. On average, students without DB disabilities scored 0.99 points higher on the MOSART posttest compared to student with DB disabilities in the same classroom holding group, pretest scores, and English proficiency constant ($p < 0.001$). In addition, students whose teachers participated in the CAP-PD scored on average 2.39 points higher on the MOSART posttest scores compared to students whose teachers did not participate, holding DB disability status, English proficiency, and pretest scores constant ($p < 0.001$). A one-point increase in student MOSART pretest is associated with a 0.29 point increase on the MOSART posttest, holding DB disability status, group, and English proficiency constant ($p < 0.001$). English language proficiency was not significantly associated with student MOSART posttest scores. In terms of variability, about 2.6% of the variance in students' scores could be attributed to the teacher level whereas 7.0%

**TABLE 7** Multilevel random intercept model results for question 2

| Variable | Coefficient | SE | *t* value | *p* value |
|---|---|---|---|---|
| Fixed effects | | | | |
| Intercept | 6.04 | 0.23 | 26.82 | 0.000 |
| *Disability Status* | −0.99 | 0.26 | −3.75 | 0.000 |
| *Group* | 2.39 | 0.32 | 7.37 | 0.000 |
| *Pretest* | 0.29 | 0.05 | 5.65 | 0.000 |
| *English Proficiency* | −0.23 | 0.52 | −0.43 | 0.664 |
| Random effects | | | *SD* | *Variance* |
| Level 3 | | | 0.41 | 0.17 |
| Level 2 | | | 0.53 | 0.28 |
| Level 1 | | | 2.45 | 6.00 |

variance in MOSART posttest scores could be accounted for based on being students in the same class with the same teacher. See Table 7 for more information.

## 3.3 | Question 3 results

The third question was: To what extent is the interaction between DB disability status and treatment exposure associated with student post-test scores holding English proficiency and pre-test scores constant? The intercept (6.05) is the grand mean of the MOSART posttest across the entire sample. The interaction between student DB disability status and their teacher's access to CAP-PD yielded a nonsignificant association with the students' MOSART posttest scores ($\beta = -0.66$, $p = 0.22$). However, student DB disability status ($\beta = -1.27$, $p < 0.001$) and whether the students' teacher participated in CAP-PD ($\beta = 2.39$, $p < 0.001$) were significantly associated with student MOSART posttest scores. In other words, when controlling for the interaction between DB disability status and group membership, group alone, English proficiency, and pretest scores, participants without DB disabilities scored 1.27 points more on the MOSART posttest than students with DB disabilities. Additionally, students whose teacher participated in CAP-PD earned 2.39 points more on the MOSART posttest compared to students whose teacher did not when holding DB disability status, English proficiency, and pretest scores constant. Additionally, a one-point increase in student MOSART pretest scores is associated with a 0.29 point increase of the posttest ($p < 0.001$) holding DB disability status, English proficiency, and groups constant. Similar to the results from Question 1, about 2.6% of the variance in students' scores could be attributed to the teacher level whereas 7.0% variance in MOSART posttest scores could be accounted for based on being students in the same class with the same teacher. See Table 8 for more information.

## 3.4 | Question 4 results

The fourth question was: To what extent are student average CBM scores associated with science achievement as assessed by post-MOSART assessment scores holding DB disability status, pre-MOSART assessment scores, and English proficiency constant? The intercept (6.05) is the grand mean of the MOSART posttest across the entire sample. Students' average CBM scores

**TABLE 8** Multilevel random intercept model results for question 3

| *Variable* | *Coefficient* | *SE* | *t value* | *p value* |
|---|---|---|---|---|
| Fixed effects | | | | |
| Intercept | 6.04 | 0.23 | 26.82 | 0.000 |
| *Disability*Group* | 0.66 | 0.54 | 1.23 | 0.219 |
| *Disability Status* | −1.27 | 0.35 | −3.63 | 0.000 |
| *Group* | 2.39 | 0.32 | 7.37 | 0.000 |
| *Pretest* | 0.29 | 0.05 | 5.64 | 0.000 |
| *English Proficiency* | −0.27 | 0.05 | −0.51 | 0.607 |
| Random effects | | | *SD* | *Variance* |
| Level 3 | | | 0.41 | 0.17 |
| Level 2 | | | 0.53 | 0.28 |
| Level 1 | | | 2.45 | 6.00 |

**TABLE 9** Multilevel random intercept model results for question 4

| **Variable** | **Coefficient** | **SE** | ***t* value** | ***p* value** |
|---|---|---|---|---|
| Fixed effects | | | | |
| Intercept | 6.05 | 0.24 | 24.85 | 0.000 |
| *CBM Average* | 0.39 | 0.04 | 8.76 | 0.000 |
| *Disability Status* | −0.72 | 0.27 | −2.64 | 0.008 |
| *Group* | 2.44 | 0.35 | 6.96 | 0.000 |
| *Pretest* | 0.22 | 0.05 | 4.25 | 0.000 |
| *English Proficiency* | 0.28 | 0.51 | 0.55 | 0.582 |
| Random effects | | | *SD* | *Variance* |
| Level 3 | | | 0.45 | 0.20 |
| Level 2 | | | 0.59 | 0.35 |
| Level 1 | | | 2.35 | 5.52 |

Abbreviation: CBM, curriculum-based measure.

were significantly related to their MOSART posttest scores. Specifically, a one-point increase on students' average CBM scores is associated with 0.39 increase on students' MOSART posttest scores, holding DB disability status, English proficiency, and pretest scores constant ($p < 0.001$). About 3.3% of the variance in students' scores could be attributed to the teacher level whereas 9.1% variance in MOSART posttest scores could be accounted for based on being students in the same class with the same teacher. See Table 9 for more information.

## 4 | DISCUSSION

Success in science achievement requires that students understand key vocabulary word meanings and how they connect to the science content (Common Core Standards, 2020; Scruggs

et al., 2013). However, developing comprehension of a multitude of specialized, complex vocabulary words is challenging for students, especially those with DB disabilities (Mason & Hedin, 2011; Scruggs et al., 2013). Although explicit vocabulary instruction enhances student science vocabulary knowledge, observational research indicates that explicit and systematic vocabulary instruction is uncommon in science classrooms (Carrier, 2013; Kaldenberg et al., 2015; Kennedy et al., 2017). In part, this is due to teachers being underprepared to provide the needed high-quality vocabulary instructional practices for students with DB disabilities (Johnson & Massey, 2012). Though recent studies suggest that professional development can enhance science teachers' vocabulary instruction practices (Kennedy et al., 2017, 2018; Lauterbach et al., 2020), limited research has examined how science teachers' access to professional development translates to increased student achievement on validated measures of science knowledge.

The purpose of this study was to determine the extent to which DB disability status, exposure to instruction by teachers who did or did not participate in the CAP-PD, and students' average performance on vocabulary-knowledge CBMs are associated with the student MOSART posttest performance measuring their science content knowledge. Overall, students without DB disabilities significantly outperformed students with DB disabilities on the MOSART posttest when they were from the same group (i.e., both had a teacher with access to the CAP-PD or both had a teacher with no access to the CAP-PD). Students with DB disabilities whose teachers had access to CAP-PD outperformed similarly classified peers whose teachers did not have access to the CAP-PD on the MOSART posttest. Likewise, students without DB disabilities whose teachers had access to the CAP-PD performed better on the MOSART posttest than students without DB disabilities whose teachers did not have access to the CAP-PD. Similar to Kennedy et al.'s (2018) study, we found that students with DB disabilities who had a teacher who participated in CAP-PD significantly outperformed their peers whose teacher did not participate in the entire CAP-PD on the MOSART posttest and science CBMs; however, our analyses also indicated that students with DB disabilities whose teacher participated in CAP-PD scored significantly higher on science vocabulary and content knowledge measures than both students with and without DB disabilities who had a teacher that did not participate in the CAP-PD (see Table 5).

Even with the significant differences in performance between students who did and did not have indirect access to the CAP-PD on their MOSART posttest scores, scores were still lower than desired. All student groups still scored below 50% on average on the MOSART posttest. While this may appear to be a discouraging outcome, it is important to note that the study took place during the first semester of the school year; therefore the MOSART's subtests included items that the students were not yet taught nor had prior knowledge to answer accurately. In addition, the MOSART measure assesses more than vocabulary, which was the focus of the PD efforts in this project. Furthermore, the MOSART assessment is not aligned to all of the state or district curricula or standards. As such, it is reasonable to assume that scores would not skyrocket because of an intervention that may not align with what students are being taught at that time of the school year.

Despite the suboptimal increase in MOSART posttest scores, a large effect size was yielded between students whose teachers participated in CAP-PD and those whose teachers did not. Students whose teachers participated in CAP-PD had an approximately two-point higher score compared to those whose teachers did not. In consideration of this being a 15-point assessment, two points would be a considerable difference in the students' scores (over a 10% score gain). This gain in student knowledge is at a relatively small cost, since the CAP-PD only involves a

few hours for teachers to become comfortable with using and creating CAP-S. In addition, the CAP materials are available online free of charge and can be customized by the teachers to meet the unique needs of their students.

Given persistent and pervasive gaps between students with and without DB disabilities in science achievement (NAEP, 2018), it is unsurprising that for every point increase a general education student earned, a student with a DB disability would have a smaller gain on their MOSART posttest when controlling for English proficiency, pretest scores, and group membership. Although this finding appears discouraging and the interaction between DB disability status and CAP-PD participation was not significant, students with and without DB disabilities whose teacher participated in CAP-PD significantly improved their performance on the MOSART posttest compared to their peers whose teacher did not participate in CAP-PD. This shows that all students may benefit from their teachers participating in CAP-PD.

Student average scores on the CBM were significantly associated with student performance on the MOSART posttest. This also supports the hypothesis that student performance on these measures would be associated with their performance on the posttest. The significant association between the CBM average scores and student MOSART posttest scores supports previous research findings of the importance of vocabulary in the learning of science content and concepts (Rupley & Slough, 2010; Therrien et al., 2011).

## 4.1 | Implications

The findings from this study extend upon the work of Kennedy et al. (2017, 2018) and Lauterbach et al. (2020), demonstrating the promise of providing science vocabulary professional development to secondary-school science teachers for improving student outcomes. As science teachers do not regularly provide evidence-based vocabulary instruction to their students, in part due to a lack of training to teach term meanings (Johnson & Massey, 2012), offering effective, research-driven professional development may help science teachers improve the experience of students when learning complex but needed science vocabulary. More research must be done with a larger sample of teachers and students to determine the degree to which the results could be generalized nationally.

Across all models, student English proficiency had a nonsignificant association with their MOSART posttest scores when controlling for their DB disability status, MOSART pretest scores, and whether their teacher participated in CAP-PD. This would suggest that multilingual students did not score significantly different from their peers whose first language is English on the science assessment. This might suggest that teacher participation in CAP-PD could help support multilingual students in gaining some of the needed science academic language. Although this was beyond the scope of the current study, future studies should investigate whether teacher participation in CAP-PD would make a significant difference in student achievement on the MOSART posttest for multilingual students with and without DB disabilities.

## 4.2 | Limitations

This study is limited by the number of participating sixth-grade teachers; the sample was underpowered, making it difficult to detect group differences on the treatment variable (MOSART

scores). This limitation makes the results hard to generalize to other science-education teachers who work in inclusive classrooms.

The results of this study support that indirect exposure to the CAP-PD has promise in enhancing students with and without DB disabilities' science achievement. In addition, the results reinforce the link between science vocabulary knowledge and achievement. However, the way specific teacher practices were used during these lessons were not considered beyond ensuring treatment fidelity.

As such, the question could be asked whether simply having a teacher who has access to CAP-PD is enough to improve science achievement, or if the quality and/or quantity of certain strategies used from the CAP-PD makes a difference in student outcomes. Future studies will need to investigate how the role of teacher behaviors regardless of having access to the CAP-PD impacts student science vocabulary and content knowledge growth. Specifically, does the use of a particular strategy or activity make a bigger difference in students science outcomes compared to using a different one?

## 5 | CONCLUSION

Many students in the United States are not proficient in science knowledge. This is in part due to the combination of the lack of high-quality instruction of science vocabulary in the classroom and science teachers being underprepared to work with students with DB disabilities effectively. Students with and without DB disabilities whose teachers participated in CAP-PD made greater gains than their peers whose teacher did not on their MOSART posttest scores. A non-significant difference in MOSART posttest scores was observed between students with DB disabilities whose teacher participated in CAP-PD and their peers without DB disabilities whose teachers did not. In addition, the average scores students earned on the CBM measures that tested their vocabulary knowledge were significantly associated with their MOSART posttest scores. Together, this suggests that knowing science vocabulary is important in enhancing student science achievement, and the provision of an evidence-based professional development targeting vocabulary instruction may lead to a more equitable and inclusive learning environment. Our field needs ongoing and new research to determine effective approaches for boosting teachers' readiness to provide high-quality instruction for all students that can result in meaningful gains in science.

## ACKNOWLEDGMENTS

The research in this article was supported by an Early Career Research and Mentoring grant awarded by the National Center for Special Education Research within the Institute for Education Sciences (Cooperative Agreement # R324B130023 to Michael Kennedy at the University of Virginia). No specific endorsement of the products reported herein on the part of the U.S. Department of Education should be inferred.

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**How to cite this article:** VanUitert, V. J., Kennedy, M. J., Peeples, K. N., Romig, J. E., Mathews, H. M., & Rodgers, W. J. (2023). Enhancing science performance of middle-school students with and without developmental and behavioral-based disabilities using the Content Acquisition Podcast Professional Development approach. *Journal of Research in Science Teaching*, *60*(3), 515–543. https://doi.org/10.1002/tea.21808